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## (54) PUMP DEVICE AND PUMP SYSTEM

PUMPVORRICHTUNG UND PUMPENSYSTEM

DISPOSITIF DE POMPE ET SYSTÈME DE POMPE

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## Description

### Technical Field

**[0001]** The present invention relates to a pump device used as a booster blower or a booster pump, for example, and to a pump system equipped with the pump device.

### Background Art

**[0002]** A pump device called booster blower or booster pump is widely known as a device that increases the pressure of gas such as a fuel gas and oxygen, liquid such as cooling water and hydraulic oil, and the like to a predetermined pressure. In this type of pump device, a roots pump, a diaphragm pump, and the like are used. For example, Patent Document 1 below describes a diaphragm pump that is used as a booster blower for fuel gas in a fuel cell system.
Moreover, Patent Document 2 below refers to a high volumetric efficiency compression machine that can be used as a compressor, pump, or actuator, with a compression chamber being formed by a movable body and the inner wall of a casing. A discharge valve is formed in the casing, and communicates with the compression chamber. Two intake valves are formed in the casing, communicate with the compression chamber and are arranged symmetrically with respect to the axial direction of the discharge valve. A rod transmits reciprocation to the movable body. Furthermore, Patent Document 3 below refers to a diaphragm pump for liquids.

Patent Document 1: Japanese Patent Application Laid-open No. 2009-47084;
Patent Document 2: US Patent Application Laid-open No. 5,201,643 A;
Patent Document 3: British Patent Application Laid-open No. 470 354 A.

### Disclosure of the Invention

### Problem to be solved by the Invention

**[0003]** A conventional booster blower does not have a function of discharging an introduced gas at a reduced pressure. For that reason, in a pump system in which a pressure source that supplies a gas of a predetermined pressure or higher is connected to a suction port of the booster blower, the gas introduced to the suction port when the operation of the booster blower is stopped is discharged from the booster blower, and depending on circumstances, there arises a possibility of causing a problem with a system.

**[0004]** In view of the circumstances as described above, it is an object of the present invention to provide a pump device and a pump system that are capable of limiting discharge of a gas when the operation is stopped.

### Means for solving the Problem

**[0005]** In order to achieve the object described above, according to an embodiment of the present invention, there is provided a pump device including a casing, a movable member, a first valve, a second valve, and a third valve.

**[0006]** The casing includes a suction port, a discharge port, and a pump chamber that can communicate with the suction port and the discharge port.

**[0007]** The movable member is movable within the casing and alternately performs suction of a gas into the pump chamber and discharge of the gas from the pump chamber.

**[0008]** The first valve is attached between the suction port and the pump chamber and permits the gas to flow from the suction port to the pump chamber.

**[0009]** The second valve is attached between the pump chamber and the discharge port and permits the gas to flow from the pump chamber to the discharge port in a case where the gas of the pump chamber has a first pressure or higher.

**[0010]** The third valve is attached to the discharge port and limits a flow of the gas toward the discharge port from the suction port in a case where the gas between the suction port and the discharge port has a second pressure or lower, the second pressure being higher than the first pressure.

**[0011]** Further, in order to achieve the object described above, according to an embodiment of the present invention, there is provided a pump system including a pump device, a pressure source, and a process unit.

**[0012]** The pump device includes a casing, a movable member, a first valve, a second valve, and a third valve.

**[0013]** The casing includes a suction port that communicates with the pressure source, a discharge port that communicates with the process unit, and a pump chamber that can communicate with the suction port and the discharge port.

**[0014]** The movable member is movable within the casing and alternately performs suction of a gas into the pump chamber and discharge of the gas from the pump chamber.

**[0015]** The first valve is attached between the suction port and the pump chamber and permits the gas to flow toward the pump chamber from the suction port.

**[0016]** The second valve is attached between the pump chamber and the discharge port and permits the gas having a first pressure or higher to flow toward the discharge port from the pump chamber.

**[0017]** The third valve is attached to the discharge port and limits a flow of the gas having a second pressure or lower to flow toward the discharge port from the suction port, the second pressure being higher than the first pressure.

**[0018]** The pressure source is connected to the suction port and supplies the gas having the second pressure or lower to the pump device.

**[0019]** The process unit is connected to the discharge port and processes the gas discharged from the pump device.

Brief Description of Drawings

**[0020]**

[Fig. 1] Fig. 1 is a diagram showing the outline of a pump system according to an embodiment of the present invention.
[Fig. 2] Fig. 2 is a cross-sectional view of a pump device according to the embodiment of the present invention.
[Fig. 3] Fig. 3 is a perspective cross-sectional view showing the configuration of a valve mechanism incorporated in the pump device.
[Fig. 4] Fig. 4 is a cross-sectional view of the valve mechanism.
[Fig. 5] Fig. 5 shows experimental results indicating a time change of a discharge flow rate of the pump device when the operation and stop of the pump device are repeated.
[Fig. 6] Fig. 6 is a configuration diagram of piping used in the experiment shown in Fig. 5.
[Fig. 7] Fig. 7 is a diagram for describing an action of the pump device.
[Fig. 8] Fig. 8 is a cross-sectional view of a pump device according to a second embodiment of the present invention.
[Fig. 9] Fig. 9 is a fragmentary exploded perspective view of a pump device according to a third embodiment of the present invention.
[Fig. 10] Fig. 10 is a diagram for describing an action of the pump device shown in Fig. 9.
[Fig. 11] Fig. 11 is a perspective view of a pump device according to a fourth embodiment of the present invention.
[Fig. 12] Fig. 12 is a cross-sectional view of a main part of the pump device shown in Fig. 11.
[Fig. 13] Fig. 13 is a front view of the pump device shown in Fig. 11.
[Fig. 14] Fig. 14 is a back view of the pump device shown in Fig. 11.
[Fig. 15] Fig. 15 is a plan view of the pump device shown in Fig. 11.
[Fig. 16] Fig. 16 is a bottom view of the pump device shown in Fig. 11.
[Fig. 17] Fig. 17 is a right side view of the pump device shown in Fig. 11.
[Fig. 18] Fig. 18 is a left side view of the pump device shown in Fig. 11.

Best Mode(s) for Carrying Out the Invention

**[0021]** According to an embodiment of the present invention, there is provided a pump device including a casing, a movable member, a first valve, a second valve, and a third valve.

**[0022]** The casing includes a suction port, a discharge port, and a pump chamber that can communicate with the suction port and the discharge port.

**[0023]** The movable member is movable within the casing and alternately performs suction of a gas into the pump chamber and discharge of the gas from the pump chamber.

**[0024]** The first valve is attached between the suction port and the pump chamber and permits the gas to flow from the suction port to the pump chamber.

**[0025]** The second valve is attached between the pump chamber and the discharge port and permits the gas to flow from the pump chamber to the discharge port in a case where the gas of the pump chamber has a first pressure or higher.

**[0026]** The third valve is attached to the casing and limits a flow of the gas toward the discharge port from the suction port in a case where the gas between the suction port and the discharge port has a second pressure or lower, the second pressure being higher than the first pressure.

**[0027]** In the pump device, the movable member periodically changes the volume of the pump chamber, and thus alternately performs the suction of the gas into the pump chamber and the discharge of the gas from the pump chamber. When the gas is suctioned, the gas is introduced from the suction port to the pump chamber via the first valve. When the gas is discharged, the gas introduced into the pump chamber is compressed to have a first pressure or higher by the movable member in the pump chamber, and thus the second valve is opened and the gas is discharged from the discharge port. By repetition of the above operation, the gas is discharged from the discharge port at a pressure equal to or higher than the first pressure.

**[0028]** The second valve is opened at the time a pressure within the pump chamber reaches the first pressure or higher, and permits the gas to flow from the pump chamber to the discharge port. So, for example, when the gas is introduced at a pressure equal to or higher than the first pressure from the suction port to the pump chamber at the time the operation of the pump device is stopped, the flow of the gas that opens the second valve and flows toward the discharge port is formed.

**[0029]** In this regard, the pump device includes a third valve. The third valve limits the flow of the gas having the second pressure or lower, the second pressure being higher than the first pressure. So, even in the case where the gas having a pressure equal to or higher than the first pressure and equal to or lower than the second pressure is introduced from the suction port to the pump chamber at the time the operation of the pump device is stopped, the gas is inhibited from flowing by the third valve and the discharge of the gas from the discharge port is suppressed. With this, an unconsidered discharge of the gas at the time the operation is stopped is suppressed.

**[0030]** Further, according to the pump device, since an unconsidered discharge of the gas at the time the operation of the pump device is stopped can be suppressed, the pump device can also be applied to a pump system in which a gas pressure source is connected to the suction port. With this, it is possible to eliminate a possibility of causing a problem with a system due to the leakage of the gas from the discharge port at the time the operation is stopped.

**[0031]** The second pressure can be set as appropriate and is set based on the pressure of the gas introduced into the suction port or an allowable flow rate of the gas discharged in a state where the operation is stopped, for example. The phrase "limit the flow" contains the meaning of "block the flow" and the meaning of "reduce the flow rate without blocking the flow".

**[0032]** The third valve is attached to the discharge port. With this, a stable pump performance can be ensured without inhibiting the gas introduced into the pump chamber from flowing.

**[0033]** The third valve may have the structure capable of completely blocking the flow of the gas having the second pressure or lower or may have the structure in which the degree of opening changes in a stepwise manner between the first pressure and the second pressure. In the former case, the third valve can be constituted of a solenoid valve, for example.

**[0034]** On the other hand, in the latter case, a valve structure in which the degree of opening increases in accordance with the pressure is adopted for the third valve. For example, the third valve includes a valve seat and a valve member that is capable of being seated on the valve seat and continuously changes the degree of opening in accordance with a pressure equal to or higher than the first pressure and equal to or lower than the second pressure. As a valve having such a valve structure, for example, an umbrella valve is applicable. With this, it is possible to control the gas discharged from the pump device at a low flow rate.

**[0035]** The casing may further include a space portion obtained by expanding a part of a flow path that communicates between the second valve and the third valve. The space portion functions as a buffer space that buffers pulsations of a discharged gas. With this, it is possible to reduce the pulsations of the gas and discharge the gas at a stable flow rate. Further, in the case where the drive of the pump device is controlled based on a discharge flow rate, it is possible to perform stable drive control of the pump device.

**[0036]** The pump device can be constituted of a diaphragm pump. In this case, the movable member includes a diaphragm that is deformable and partitions the pump chamber. With this, it is possible to provide a small pump device.

**[0037]** According to an embodiment of the present invention, there is provided a pump system including a pump device, a pressure source, and a process unit.

**[0038]** The pump device includes a casing, a movable member, a first valve, a second valve, and a third valve.

**[0039]** The casing includes a suction port that communicates with the pressure source, a discharge port that communicates with the process unit, and a pump chamber that can communicate with the suction port and the discharge port.

**[0040]** The movable member is movable within the casing and alternately performs suction of a gas into the pump chamber and discharge of the gas from the pump chamber.

**[0041]** The first valve is attached between the suction port and the pump chamber and permits the gas to flow toward the pump chamber from the suction port.

**[0042]** The second valve is attached between the pump chamber and the discharge port and permits the gas having a first pressure or higher to flow toward the discharge port from the pump chamber.

**[0043]** The third valve is attached to the casing and limits a flow of the gas having a second pressure or lower to flow toward the discharge port from the suction port, the second pressure being higher than the first pressure.

**[0044]** The pressure source is connected to the suction port and supplies the gas having the second pressure or lower to the pump device.

**[0045]** The process unit is connected to the discharge port and processes the gas discharged from the pump device.

**[0046]** According to the pump system, even in the case where the gas having a pressure equal to or higher than the first pressure and equal to or lower than the second pressure is introduced from the pressure source to the pump chamber at the time the operation of the pump device is stopped, the gas is inhibited from flowing by the third valve and the discharge of the gas from the discharge port is limited. With this, an unconsidered discharge of the gas at the time the operation is stopped is suppressed. Further, it is possible to eliminate a possibility of causing a problem with a system due to the leakage of the gas from the discharge port at the time the operation is stopped.

**[0047]** The process unit is not particularly limited and includes various devices for generating energy and power by using the gas discharged from the pump device, such as a reformer, a combustor, a power generator, a cylinder device, and various engines.

**[0048]** Hereinafter, embodiments of the present invention will be described with reference to the drawings.

<First Embodiment>

[Pump System]

**[0049]** Fig. 1 is a diagram showing the outline of a pump system according to an embodiment of the present invention. A pump system 1 of this embodiment includes a pressure source 2, a pump device 3, a process unit 4, and a control unit 5.

**[0050]** The pressure source 2 is connected to a suction side (primary side) of the pump device 3, and the process unit 4 is connected to a discharge side (secondary side) of the pump device 3. The pressure source 2 may be a container such as a tank and a cylinder to contain a gas of a predetermined pressure or may be a pressure generation source such as a compressor. The pump device 3 functions as a booster blower or a booster pump that increases a pressure PI of the gas, which is introduced from the pressure source 2, to a predetermined pressure P2 and supplies the gas to the process unit 4. The process unit 4 processes the gas supplied from the pump device 3 and generates energy, power, and the like. The control unit 5 controls the operation of the pump device 3, but may control the whole system including the process unit 4.

**[0051]** The pump system 1 is applied to a fuel cell system, for example. In this case, the pressure source 2 corresponds to a fuel tank, and the pump device 3 boosts fuel gas (for example, city gas (methane) or LPG (liquefied propane gas)) and supplies the fuel gas to the process unit 4. The process unit 4 includes a reformer that transforms the fuel gas into hydrogen, a fuel cell that accumulates hydrogen, a power generation unit that causes hydrogen to react with oxygen, and the like.

[Pump Device]

**[0052]** Next, the pump device 3 will be descried in detail with reference to Fig. 2. Fig. 2 is a cross-sectional view showing the configuration of the pump device 3. In this embodiment, the pump device 3 is constituted of a diaphragm pump.

**[0053]** The pump device 3 includes a metallic casing 10 and a drive unit 20. The casing 10 includes a pump body 11, a pump head 12, and a pump head cover 13. The drive unit 20 includes a motor 21 and a motor case 22.

**[0054]** The pump body 11 forms an operating space 105 inside the casing 10, the operating space 105 containing a movable member 30. The movable member 30 includes a diaphragm 31, a fixture 32 that is fixed to the diaphragm 31, and a connecting rod 33 that couples the fixture 32 to the motor 21.

**[0055]** The diaphragm 31 is formed of a disk-shaped rubber material, and its outer edge is sandwiched between the pump body 11 and the pump head 12. The fixture 32 is fixed to the center portion of the diaphragm 31 and is constituted of a plurality of components that are assembled so as to sandwich the diaphragm 31 in upward and downward direction. The connecting rod 33 is integrated with the fixture 32 so as to penetrate the center portion of the diaphragm 31. The connecting rod 33 is coupled to the periphery of an eccentric cam 35 via a bearing 34, the eccentric cam 35 being attached to a rotary shaft 210 of the motor 21.

**[0056]** The pump head 12 includes a suction port 101 and a discharge port 102 and is disposed on the upper surface of an annular seating 110. The seating 110 is attached to an opening end of an upper portion of the pump body 11 and sandwiches the outer edge of the diaphragm 31 together with the pump head 12. The pump head 12 forms a pump chamber 100 together with the diaphragm 31.

**[0057]** The pump head 12 includes a suction passage T1 that communicates between the suction port 101 and the pump chamber 100, and a discharge passage T2 that communicates between the pump chamber 100 and the discharge port 102. The pump chamber 100 is capable of communicating with the suction port 101 and the discharge port 102 via the suction passage T1 and the discharge passage T2, respectively. A suction valve 41 (first valve) and a discharge valve 42 (second valve) are attached to the suction passage T1 and the discharge passage T2, respectively.

**[0058]** The suction valve 41 is attached to the pump head 12 so as to occlude a suction hole h1 that forms the suction passage T1. The suction valve 41 is constituted of a reed valve attached to an end of the suction hole h1 facing the pump chamber 100 and permits the gas to flow toward the pump chamber 100 from the suction port 101. The valve opening pressure of the suction valve 41 (minimum pressure required to open the suction valve 41) is not particularly limited and only needs to be a valve opening pressure enough to introduce gas of a predetermined flow rate (throughput) to the pump chamber 100 at the time the pump device is operated. So, the valve opening pressure of the suction valve 41 may be a pressure lower than the pressure of the gas supplied from the pressure source 2 to the pump device 3.

**[0059]** On the other hand, the discharge valve 42 is attached to the pump head 12 so as to occlude a discharge hole h2 that forms the discharge passage T2. The discharge valve 42 is constituted of a reed valve attached to an end of the discharge hole h2 on the opposite side to the pump chamber 100 and permits the gas to flow toward the discharge port 102 from the pump chamber 100. The valve opening pressure of the discharge valve 42 (minimum pressure required to open the discharge valve 42) is, without being particularly limited, set to a pressure at which a target discharge pressure is obtained, and in this embodiment, set to a pressure (first pressure) higher than the valve opening pressure of the suction valve 41.

**[0060]** The pump head cover 13 is attached to the upper portion of the pump head 12. Each of the suction passage T1 and the discharge passage T2 is formed by combination of the pump head 12 and the pump head cover 13. The pump body 11, the pump head 12, and the pump head cover 13 are integrally fixed using a plurality of screw members B.

**[0061]** The motor 21 is constituted of a direct-current brushless motor capable of controlling the rotation speed and is contained in the cylindrical motor case 22. The motor 21 includes the rotary shaft 210, a stator 211, and a rotor 212. The stator 211 is fixed to an inner surface of the motor case 22, and the rotor 212 is fixed to a circumference of the rotary shaft 210. The rotary shaft 210 is supported by the motor case 22 via bearings 23 and 24, and a tip end of the rotary shaft 210 is attached to the rotation center of the eccentric cam 35.

**[0062]** The eccentric cam 35 is formed such that its rotation center is eccentric relative to the inner race of the bearing 34. So, when the rotary shaft 210 rotates about its axis by the drive of the motor 21, the eccentric cam 35 rotates together with the rotary shaft 210, and thus the movable member 30 reciprocates vertically within the operating space 105. With this, the volume of the pump chamber 100 periodically changes and a predetermined pump function is obtained. The amount of reciprocation of the movable member 30 (stroke amount) is determined by an eccentricity amount of the eccentric cam 35.

**[0063]** The pump device 3 further includes a valve mechanism 50 (third valve). The valve mechanism 50 is attached to the discharge port 102. The valve mechanism 50 has a function of limiting the outflow of gas from the discharge port 102 at the time the operation of the pump device 3 is stopped.

**[0064]** Fig. 3 is a perspective cross-sectional view showing the configuration of the valve mechanism 50, and Fig. 4 is a cross-sectional view thereof. The valve mechanism 50 includes a valve member 51 made of rubber and a metallic housing 52 that contains the valve member 51.

**[0065]** The housing 52 includes a first end 521 connected to the discharge port 102 of the casing 10 and a second end 522 connected to a pipe line (not shown) that communicates with the process unit 4. A seal ring 54 is fitted to the circumference of the first end 521, and the first end 521 is hermetically attached to the inside of the discharge port 102 by the seal ring 54.

**[0066]** Inside the housing 52, an inner passage 523 that communicates between the first end 521 and the second end 522 is formed. Almost at the center portion of the inner passage 523, a wall portion 53 including a plurality of holes 531 at its center portion and circumference is formed perpendicularly to a wall surface of the inner passage 523, and the first end 521 and the second end 522 are capable of communicating with each other via those holes 531.

**[0067]** The valve member 51 is constituted of an umbrella valve. Specifically, the valve member 51 is formed into almost a disk shape and a shaft portion 511 formed at the center portion of the valve member 51 is fitted to a center hole of the wall portion 53. Thus, the valve member 51 is disposed in the inner passage 523. An outer edge 512 of the valve member 51 is elastically in contact with a valve seat 532 that is formed on a front surface of the wall portion 53 facing the second end 522, and stops the flow of the gas from the second end 522 side to the first end 521 side. Specifically, the valve member 51 functions as a backflow prevention valve.

**[0068]** On the other hand, the valve member 51 permits the gas to flow in the forward direction from the first end 521 side to the second end 522 side by opening the valve at a predetermined pressure or higher. In this case, as shown in Fig. 4, the valve member 51 moves away from the valve seat 532 because the outer edge 512 is elastically deformed to the second end 522 side, and a blocking state of the inner passage 523 by the valve member 51 is released. Under a gas pressure lower than the predetermined pressure, the outer edge 512 is seated on the valve seat 532, and the blocking state of the inner passage 523 is maintained.

**[0069]** A rubber material having resistance to various process gases is used for the valve member 51. For example, in the case where methane, propane, or the like is used as process gas, rubber materials having resistance to hydrocarbon gas including methane and propane, such as nitrile rubber (NBR), hydrogenated nitrile rubber (HNBR), and fluoro-rubber (FKM), are used for the valve member 51. The thickness or size of the valve member 51 is not particularly limited and is set to a thickness or size enough to ensure a valve opening pressure compatible with various specifications.

**[0070]** Specifically, the valve opening pressure of the valve member 51 (minimum pressure required to open the valve member 51) is set to a pressure that is at least higher than the valve opening pressure (first pressure) of the discharge valve 42. Thus, the valve member 51 limits the flow of gas having a predetermined pressure (second pressure) or lower, the predetermined pressure (second pressure) being higher than the valve opening pressure of the valve member 51.

**[0071]** The valve opening pressure of the valve member 51 is determined by referring to the gas pressure Pl supplied from the pressure source 2 of the pump system 1. In this embodiment, the valve opening pressure of the valve member 51 is set to a pressure higher than the gas pressure Pl of the pressure source 2. With this, even in the case where the gas pressure Pl of the pressure source 2 is higher than the valve opening pressure of the discharge valve 42, it is possible to block the outflow of gas from the discharge port 102 to the process unit 4 when the operation of the pump device 3 is stopped and reliably prevent the outflow of gas to the process unit 4.

**[0072]** It should be noted that as will be described later, the valve opening pressure of the valve member may be set to a pressure lower than the gas pressure P2 of the pressure source 2.

[Operation of Pump Device]

**[0073]** Next, a typical operation example of the pump device 3 configured as described above will be described.

**[0074]** The pump device 3 is driven by activation of the motor 21 of the drive unit 20. The rotation speed of the motor 21 is controlled by the control unit 5 so as to obtain a constant discharge flow rate based on a flowmeter provided on the discharge side of the pump device 3, for example. The motor 21 reciprocates the movable member 30 in the operating space 105 with predetermined strokes by rotating the eccentric cam 35 via the rotary shaft 210. With this, the diaphragm 31 that partitions the pump chamber 100 moves up and down, and the volume of the pump chamber 100 changes periodically.

**[0075]** The movable member 30 periodically changes the volume of the pump chamber 100 and thus alternately performs the suction of gas into the pump chamber 100 and the discharge of gas from the pump chamber 100. Specifically, the fuel gas of the pressure PI (for example, 2 kPa (gauge pressure)) is introduced into the pump chamber 100 via the suction valve 41 from the pressure source 2 connected to the suction port 101. The fuel gas introduced into the pump chamber 100 is compressed by the movable member in the pump chamber 100 and is boosted. Thus, the discharge valve 42 and the valve mechanism 50 are opened. By repetition of the above operation, the fuel gas of the pressure P2 (for example, 15 kPa (gauge pressure)) is discharged from the discharge port 102 to the process unit 4.

**[0076]** Here, the discharge valve 42 is opened at the time when the pressure within the pump chamber 100 reaches the valve opening pressure of the discharge valve 42 or higher and permits the gas to flow from the pump chamber 100 to the discharge port 102. So, when the gas is introduced into the pump chamber 100 from the suction port 101 at a pressure equal to or higher than the valve opening pressure of the discharge valve 42 when the operation of the pump device 3 is stopped, the discharge valve 42 is opened and the flow of the gas toward the discharge port 102 is formed.

**[0077]** In this regard, in the pump device 3 of this embodiment, the valve mechanism 50 is attached to the discharge port 102. The valve mechanism 50 has a valve opening pressure that is higher than the gas pressure (P1) of the pressure source 2. So, even in the case where the gas of the pressure PI is introduced from the suction port 101 to the pump chamber 100 when the operation of the pump device 3 is stopped, the flow of the gas is stopped by the valve mechanism 50 and the outflow of the gas from the discharge port 102 to the process unit 4 is prevented. In such a manner, since an unconsidered discharge of the gas when the operation is stopped is suppressed, it is possible to eliminate a possibility of causing a problem with a system.

**[0078]** Further, in this embodiment, the valve mechanism 50 has the structure capable of continuously changing the degree of opening in accordance with an introduction pressure. With this, at the time the operation of the pump device 6 is restarted, the valve mechanism 50 can be opened in accordance with a discharge pressure, and gas of a necessary flow rate can be supplied to the process unit 4 rapidly.

**[0079]** Fig. 5 shows a time change of the discharge flow rate of the pump device 3 when the operation and stop of the pump device 3 are repeated under experimental conditions shown in Fig. 6. In Fig. 6, a is a buffer tank, b is a pressure gauge, c is suction piping, and d is a blower, which correspond to the pump device 3 of this embodiment. e is a pressure gauge, f is discharge piping, g is a fixed orifice, and h is a flowmeter.

**[0080]** As shown in Fig. 5, it was found that the minimum value of the discharge flow rate is zero and a function of confining gas by the valve mechanism 50 normally works when the operation of the pump device 3 is stopped. Further, it was also found that the discharge flow rate of the pump device 6 is stably maintained to have a constant value and reproducibility is high.

**[0081]** Fig. 7 shows experimental results that indicate a change in discharge flow rate of the pump device 6 with respect to a rotation speed control voltage (Vsp) input to the motor 21 of the pump device 6. A piping system in which the pump device 6 is incorporated is the same as the piping example shown in Fig. 6.

**[0082]** As shown in Fig. 7, it was found that after the operation of the pump device is started, the discharge of gas is started at the time the rotation speed reaches a predetermined rotation speed and its flow rate rises substantially in proportion to the driving rotation speed of the pump device. In such a manner, according to this embodiment, the function of confining gas and the stable control on the discharge flow rate can be achieved.

<Second Embodiment>

**[0083]** Fig. 8 shows a pump device according to a second embodiment of the present invention. Hereinafter, a configuration different from that of the first embodiment will be mainly described, and the configurations that are the same as those in the embodiment described above will be denoted by the same reference numerals and description thereof will be omitted or simplified.

**[0084]** A pump device 6 of this embodiment is different from that of the first embodiment described above in the configuration of a valve mechanism 60 attached to the discharge port 102. The valve mechanism 60 includes a valve member 61 that configures an umbrella valve, and is provided in the inner passage of a housing 62 in the same form as in the first embodiment shown in Figs. 3 and 4.

**[0085]** The valve mechanism 60 of this embodiment has a function common to the first embodiment, the function of limiting the outflow of gas having the valve opening pressure (first pressure) or higher of the discharge valve 42 and the gas pressure PI (second pressure) or lower of the pressure source 2. However, the valve mechanism 60 of this embodiment is different from that of the first embodiment in that the valve mechanism 60 has a function of permitting gas to outflow from the discharge port 102 to the process unit 4 while suppressing the outflow to a predetermined amount or less when the operation of the pump device 6 is stopped.

**[0086]** Specifically, the valve opening pressure of the valve member 61 of this embodiment is set to a pressure lower than the gas pressure PI of the pressure source 2. Since the valve mechanism 60 of the this embodiment has the structure capable of continuously changing the degree of opening in accordance with the gas pressure, the flow rate of gas outflowing to the process unit 4 side can be controlled in accordance with the pressure of gas introduced into the valve mechanism 60.

**[0087]** In this case, a pressure required to fully open the valve member 61 is set to a pressure higher than the gas pressure P1 of the pressure source 2 (for example, equal to or lower than the discharge pressure (P2) at the time of normal operation of the pump device 3). With this, the flow rate of gas having the valve opening pressure (first pressure) or higher of the discharge valve 42 and the gas pressure P1 (second pressure) or lower of the pressure source 2 can be controlled by the valve mechanism 60.

**[0088]** According to this embodiment, when the operation of the pump device 6 is stopped, the flow rate of gas supplied from the pressure source 2 can be adjusted to a predetermined flow rate to be supplied to the process unit 4. With this, it is unnecessary to separately provide a throttle valve such as an orifice on an upstream or downstream side of the pump device 6, and this allows the number of components of the system to be reduced. This embodiment is suitably used for a system that needs to supply gas of a predetermined flow rate or lower to the process unit 4 also when the operation of the pump device 6 is stopped.

<Third Embodiment>

**[0089]** Fig. 9 shows a pump device according to a third embodiment of the present invention. Hereinafter, a configuration different from that of the first embodiment will be mainly described, and the configurations that are the same as those in the embodiments described above will be denoted by the same reference numerals and description thereof will be omitted or simplified.

**[0090]** A pump device 7 of this embodiment includes a casing 70 including a pump body 11, a pump head 72, and a pump head cover 73. A suction port 101 and a discharge port 102 are formed in the pump head 72. The valve mechanism 50 described in the first embodiment is attached to the discharge port 102.

**[0091]** Further, a suction passage T1, a discharge passage T2, and a buffer tank 721 are formed in the pump head 72. At least a part of each of those passages is exposed to the outside from the upper surface of the pump head 72 and is covered with the pump head cover 73 via a seal member to be isolated from open air.

**[0092]** In general, a diaphragm pump structurally generates pulsations in discharge gas. In the case where the driving rotation speed of the pump is controlled based on a measured value of the flow rate of discharge gas, when a pulsation is large, a correct flow rate cannot be measured and the drive control of the pump becomes unstable. Further, in the case where the discharge gas is fuel gas, there is a possibility that the pulsations cause unstable combustion or incomplete combustion.

**[0093]** In this regard, the pump device 7 of this embodiment includes the buffer tank 721 between the discharge passage T2 and the discharge port 102. The buffer tank 721 forms a space portion 74 between a discharge valve 42 (discharge passage T2) and the valve mechanism 50 by expanding a part of a flow path that communicates with the discharge valve 42 (discharge passage T2) and the valve mechanism 50. The buffer tank 721 has a function of buffering the pulsations of gas discharged from the discharge valve 42.

**[0094]** According to the pump device 7 of this embodiment, it is possible to reduce the pulsations of gas discharged from the valve mechanism 50 and discharge gas at a stable flow rate. Further, in the case where the drive of the pump device 7 is controlled based on the discharge flow rate, it is possible to perform stable drive control of the pump device 7. Further, since the pump and the buffer tank are integrated, it is not necessary to separately provide a buffer tank in the gas flow path of the pump system, and the system configuration can be simplified.

**[0095]** The volume of the space portion 74 of the buffer tank 721 is determined based on the pulsations (pressure range) of the gas discharged from the discharge valve 42. Fig. 10 shows results of an experiment performed by the inventors of the present invention and shows a relationship between a buffer volume (cc) and a pressure range of gas discharged from the discharge port 102. As shown in Fig. 10, as the volume of the space portion 74 becomes larger, the pressure range can be made smaller. For example, when the volume of the space portion 74 is set to 120 cc or more, the pulsation range can be reduced to 0.75 kPa or less.

<Fourth Embodiment>

**[0096]** Fig. 10 shows a pump device according to a fourth embodiment of the present invention. Hereinafter, a configuration different from that of the first embodiment will be mainly described, and the configurations that are the same as those in the embodiments described above will be denoted by the same reference numerals and description thereof will be omitted or simplified.

**[0097]** A pump device 8 of this embodiment includes a casing 80, a drive unit 20, and a buffer tank 81. The casing 80 includes a suction port 101 and a discharge port 102, boosts gas suctioned from the suction port 101 in a pump chamber (not shown), and discharges the boosted gas from the discharge port 102 via the buffer tank 81.

**[0098]** Fig. 11 is a cross-sectional view of the buffer tank 81 and the discharge port 102. A space portion 74 having a predetermined volume is formed within the buffer tank 81 and reduces pulsations of the discharge gas. The discharge port 102 communicates with the space portion 74, and a valve member 51 is attached to the inside of the discharge port 102. The valve member 51 has the same configuration as that of the first embodiment and has a function of limiting the outflow of gas having a predetermined pressure or less.

**[0099]** Also in this embodiment configured as described above, the same actions and effects as those of the embodiments described above can be obtained. According to the pump device 8 of this embodiment, since the valve member 51 as a valve mechanism is supported by the casing 80, the number of components can be reduced.

**[0100]** It should be noted that Figs. 13 to 18 each show an outer appearance of the pump device 8. Fig. 13 is a front view, Fig. 14 is a back view, Fig. 15 is a plan view, Fig. 16 is a bottom view, Fig. 17 is a right side view, and Fig. 18 is a left side view.

**[0101]** Hereinabove, the embodiments of the present invention have been described, but the present invention is not limited to the embodiments described above and can be variously modified without departing from the gist of the present invention as a matter of course.

**[0102]** For example, in the embodiments described above, the valve mechanism that limits the flow of the gas having a predetermined pressure or lower is attached to the discharge port, but the present invention is not limited thereto. For example, the valve mechanism may be provided on a discharge passage between the discharge valve and the discharge port.

**[0103]** Further, the valve member that constitutes the valve mechanism is not limited to the umbrella valve and may be constituted of a ball valve or a butterfly valve, for example.

**[0104]** Furthermore, in the embodiments described above, the pump device is constituted of the diaphragm pump, but the present invention is not limited thereto and can also be applied to another pump device such as a roots pump. In the case of a roots pump, the movable member that changes the volume of the pump chamber corresponds to rotors disposed to be opposed to each other.

Description of Reference Numerals

**[0105]**

| | |
|---|---|
| 1 | pump system |
| 2 | pressure source |
| 3, 6, 7, 8 | pump device |
| 4 | process unit |
| 10, 70, 80 | casing |
| 20 | drive unit |
| 30 | movable member |
| 31 | diaphragm |
| 41 | suction valve |
| 42 | discharge valve |
| 50, 60 | valve mechanism |
| 51, 61 | valve member |
| 74 | space portion |
| 100 | pump chamber |
| 101 | suction port |
| 102 | discharge port |

**Claims**

1. A pump device (3; 6; 7; 8), comprising:

    a casing (10; 70; 80) including
    a suction port (101), a discharge port (102), and a pump chamber (100) that can communicate with the suction port (101) and the discharge port (102);
    a movable member (30) that is movable within the casing (10; 70; 80) and alternately performs suction of a gas into the pump chamber (100) and discharge of the gas from the pump chamber (100);
    a first valve that is attached between the suction port (101) and the pump chamber (100) and permits the gas to flow from the suction port (101) to the pump chamber (100);
    a second valve that is attached between the pump chamber (100) and the discharge port (102) and permits the gas to flow from the pump chamber (100) to the discharge port (102) in a case where the gas of the pump chamber (100) has a first pressure or higher; **characterised in that** a third valve that is attached to the discharge port (102) and limits a flow of the gas toward the discharge port (102) from the suction port (101) in a case where the gas between the suction port (101) and the discharge port (102) has a second pressure or lower, the second pressure being higher than the first pressure.

2. The pump device (3; 6; 7; 8) according to claim 1, wherein
the third valve includes a valve member (51; 61) that continuously changes the degree of opening in accordance with a pressure equal to or higher than the first pressure and equal to or lower than the second pressure.

3. The pump device (3; 6; 7; 8) according to claim 2, wherein
the valve member (51; 61) is an umbrella valve.

4. The pump device (3; 6; 7; 8) according to claim 1, wherein
the casing (10; 70; 80) further includes a space portion obtained by expanding a part of a flow path that communicates between the second valve and the third valve.

5. The pump device (3; 6; 7; 8) according to claim 1, wherein
the movable member (30) includes a diaphragm that is deformable and partitions the pump chamber

(100).

6. A pump system (1), comprising:

a pump device (3; 6; 7; 8) including

a casing (10; 70; 80) including

a suction port (101) that communicates with a pressure source, a discharge port (102) that communicates with a process unit, and a pump chamber (100) that can communicate with the suction port (101) and the discharge port (102),

a movable member (30) that is movable within the casing (10; 70; 80) (100) and alternately performs suction of a gas into the pump chamber (100) and discharge of the gas from the pump chamber (100),
a first valve that is attached between the suction port (101) and the pump chamber (100) and permits the gas to flow toward the pump chamber (100) from the suction port (101),
a second valve that is attached between the pump chamber (100) and the discharge port (102) and permits the gas having a first pressure or higher to flow toward the discharge port (102) from the pump chamber (100), and
a third valve that is attached to the discharge port (102) and limits a flow of the gas having a second pressure or lower to flow toward the discharge port (102) from the suction port (101), the second pressure being higher than the first pressure;

a pressure source (2) that is connected to the suction port (101) and supplies the gas having the second pressure or lower to the pump device (3; 6; 7; 8); and
a process unit (4) that is connected to the discharge port (102) and processes the gas discharged from the pump device (3; 6; 7; 8).

7. The pump system (1) according to claim 6, wherein the third valve includes a valve member (51; 61) that blocks the flow of the gas having the second pressure or lower.

8. The pump system (1) according to claim 6, wherein the third valve includes a valve member (51; 61) that continuously changes the degree of opening in accordance with a pressure equal to or higher than the first pressure and equal to or lower than the second pressure.

**Patentansprüche**

1. Pumpenvorrichtung (3; 6; 7; 8) aufweisend:

ein Gehäuse (10; 70; 80) einschließlich

eines Sauganschlusses (101), eines Auslassanschlusses (102), und einer Pumpenkammer (100), die mit dem Sauganschluss (101) und dem Auslassanschluss (102) kommunizieren kann;

ein bewegbares Glied (30) das bewegbar innerhalb des Gehäuses (10; 70; 80) ist und alternativ das Einsaugen eines Gases in die Pumpenkammer (100) und das Auslassen des Gases aus der Pumpenkammer (100) durchführt;
ein erstes Ventil, das zwischen dem Sauganschluss (101) und der Pumpenkammer (100) angebracht ist und es dem Gas ermöglicht, von dem Sauganschluss (101) zu der Pumpenkammer (100) zu fließen;
ein zweites Ventil, das zwischen der Pumpenkammer (100) und dem Auslassanschluss (102) angebracht ist und es dem Gas ermöglicht, von der Pumpenkammer (100) zu dem Auslassanschluss (102) zu fließen, in einem Fall, in dem das Gas der Pumpenkammer (100) einen ersten Druck oder einen höheren Druck hat;

**dadurch gekennzeichnet, dass**

ein drittes Ventil, das an dem Auslassanschluss (102) angebracht ist, und einen Fluss des Gases von dem Sauganschluss (101) zu dem Auslassanschluss (102) hin in einem solchen Fall begrenzt, in dem das Gas zwischen dem Sauganschluss (101) und dem Auslassanschluss (102) einen zweiten Druck oder einen niedrigeren Druck hat, wobei der zweite Druck größer als der erste Druck ist.

2. Pumpenvorrichtung (3; 6; 7; 8) nach Anspruch 1, wobei das dritte Ventil ein Ventilglied (51; 61) umfasst, das kontinuierlich den Grad der Öffnung gemäß einem Druck größer oder gleich dem ersten Druck und kleiner oder gleich dem zweiten Druck ändert.

3. Pumpenvorrichtung (3; 6; 7; 8) nach Anspruch 2, wobei das Ventilglied (51; 61) ein Rückschlagventil ist.

4. Pumpenvorrichtung (3; 6; 7; 8) nach Anspruch 1, wobei das Gehäuse (10; 70; 80) ferner einen Raumabschnitt umfasst, der dadurch erhalten wird, dass ein Teil eines Fließweges, der zwischen dem zweiten Ventil und dem dritten Ventil eine Verbindung

schafft, ausgedehnt wird.

**5.** Pumpenvorrichtung (3; 6; 7; 8) nach Anspruch 1, wobei das bewegbare Glied (30) eine Membran umfasst, die verformbar ist und die Pumpenkammer (100) unterteilt.

**6.** Pumpenanordnung (1), aufweisend:

eine Pumpenvorrichtung (3; 6; 7; 8) umfassend

ein Gehäuse (10; 70; 80) einschließlich

eines Sauganschlusses (101), der mit einer Druckquelle in Verbindung steht, eines Auslassanschlusses (102), der mit einer Verarbeitungseinheit in Verbindung steht, und einer Pumpenkammer (100), die mit dem Sauganschluss (101) und dem Auslassanschluss (102) kommunizieren kann;

ein bewegbares Glied (30) das bewegbar innerhalb des Gehäuses (10; 70; 80) (100) ist und alternativ das Einsaugen eines Gases in die Pumpenkammer (100) und das Auslassen des Gases aus der Pumpenkammer (100) durchführt;
ein erstes Ventil, das zwischen dem Sauganschluss (101) und der Pumpenkammer (100) angebracht ist und es dem Gas ermöglicht, von dem Sauganschluss (101) zu der Pumpenkammer (100) zu fließen;
ein zweites Ventil, das zwischen der Pumpenkammer (100) und dem Auslassanschluss (102) angebracht ist und es dem Gas, das einen ersten Druck oder einen höheren Druck hat, ermöglicht, von der Pumpenkammer (100) zu dem Auslassanschluss (102) zu fließen; und
ein drittes Ventil, das an dem Auslassanschluss (102) angebracht ist und einen Fluss des Gases, das einen zweiten Druck oder einen niedrigeren Druck hat, von dem Sauganschluss (101) zu dem Auslassanschluss (102) hin begrenzt, wobei der zweite Druck größer als der erste Druck ist;
eine Druckquelle (2), die mit dem Sauganschluss (101) verbunden ist und das Gas, das den zweiten Druck oder einen niedrigeren Druck hat, an die Druckvorrichtung (3; 6; 7; 8) bereitstellt; und
eine Verarbeitungseinheit (4), die mit dem Auslassanschluss (102) verbunden ist und das von der Pumpenvorrichtung (3; 6; 7; 8) abgegebene Fas verarbeitet.

**7.** Pumpenanordnung (1) nach Anspruch 6, wobei das dritte Ventil ein Ventilglied (51; 61) umfasst, das den Strom von dem Gas blockiert, das den zweiten Druck oder einen niedrigeren Druck hat.

**8.** Pumpenanordnung (1) nach Anspruch 6, wobei das dritte Ventil ein Ventilglied (51; 61) umfasst, das kontinuierlich den Grad der Öffnung gemäß einem Druck größer oder gleich dem ersten Druck und kleiner oder gleich dem zweiten Druck ändert.

**Revendications**

**1.** Dispositif de pompe (3 ; 6 ; 7 ; 8), comportant :

un boîtier (10 ; 70 ; 80) incluant:

une embouchure d'aspiration (101), une embouchure d'évacuation (102), et une chambre de pompe (100) qui peut communiquer avec l'embouchure d'aspiration (101) et l'embouchure d'évacuation (102);
un organe mobile (30) qui est mobile à l'intérieur du boîtier (10 ; 70 ; 80) et qui, alternativement effectue une aspiration de gaz dans la chambre (100) de la pompe et évacue le gaz de la chambre (100) de la pompe ;
une première valve qui est montée entre l'embouchure d'aspiration (101) et la chambre (100) de la pompe et qui permet au gaz de circuler de l'embouchure d'aspiration (101) vers la chambre (100) de la pompe ;
une seconde valve qui est montée entre la chambre (100) de la pompe et l'embouchure d'évacuation (102) et qui permet au gaz de circuler de la chambre (100) de la pompe vers l'embouchure d'évacuation (102) au cas où le gaz de la chambre (100) de la pompe a une première pression ou supérieure ;
**caractérisé en ce qu'**
une troisième valve est liée à la soupape d'évacuation (102) et limite un flux de gaz vers l'embouchure d'évacuation (102) depuis l'embouchure d'aspiration (101) dans le cas où le gaz, entre l'embouchure d'aspiration (101) et l'embouchure d'évacuation (102) a une seconde pression ou inférieure, la seconde pression étant supérieure à la première pression.

**2.** Dispositif de pompe (3 ; 6 ; 7 ; 8), selon la revendication 1, dans lequel la troisième valve comporte un organe de valve (51 ; 61) qui modifie continuellement le degré d'ouverture en accord avec une pression égale à ou supérieure à la première pression et égale à ou inférieure à la seconde pression.

**3.** Dispositif de pompe (3 ; 6 ; 7 ; 8), selon la revendication 2, dans lequel l'organe de valve (51 ; 61) est une valve en forme d'ombrelle.

**4.** Dispositif de pompe (3 ; 6 ; 7 ; 8), selon la revendication 1, dans lequel
le boîtier (10 ; 70 ; 80) comporte en outre une zone d'espace obtenu en étendant une partie de la trajectoire du flux qui communique entre le seconde valve et la troisième valve.

**5.** Dispositif de pompe (3 ; 6 ; 7 ; 8), selon la revendication 1, dans lequel
l'organe mobile (30) comporte un diaphragme qui est déformable et partitionne la chambre (100) de la pompe.

**6.** Système de pompe (1), comportant :

un dispositif de pompe (3 ; 6 ; 7; 8), incluant

un boîtier (10 ; 70 ; 80) incluant

une embouchure d'aspiration (101) qui communique avec une source de pression, une embouchure d'évacuation (102) qui communique avec une unité de traitement, et une chambre de pompe (100) qui peut communiquer avec l'embouchure d'aspiration (101) et l'embouchure d'évacuation (102),
un organe mobile (30) qui est mobile à l'intérieur du boîtier (10 ; 70 ; 80) (100) et qui, alternativement effectue une aspiration de gaz dans la chambre (100) de la pompe et évacue le gaz de la chambre (100) de la pompe ;
une première valve qui est montée entre l'embouchure d'aspiration (101) et la chambre (100) de la pompe et qui permet au gaz de circuler de la chambre (100) de la pompe vers l'embouchure d'aspiration (101),
une seconde valve qui est montée entre la chambre (100) de la pompe et l'embouchure d'évacuation (102) et qui permet au gaz ayant une première pression ou supérieure, de circuler vers l'embouchure d'évacuation (102) depuis la chambre (100) de la pompe; et
une troisième valve qui est liée à l'embouchure d'évacuation (102) et limite un flux de gaz ayant une seconde pression ou inférieure de circuler vers l'embouchure d'évacuation (102) depuis l'embouchure d'aspiration (101), la seconde pression étant supérieure à la première pression ;

une source de pression (2) qui est connectée à l'embouchure d'aspiration (101) et fournit le gaz ayant la seconde pression ou inférieure au dispositif de pompe (3 ; 6 ; 7 ; 8); et
une unité de pression (4) qui est connectée à l'embouchure d'évacuation (102) et traite le gaz évacué par le dispositif de pompe (3 ; 6 ; 7 ; 8).

**7.** Système de pompe (1) selon la revendication 6, dans lequel la troisième valve comporte un organe de valve (51 ; 61) qui bloque le flux de gaz ayant la seconde pression ou inférieure.

**8.** Système de pompe (1) selon la revendication 6, dans lequel la troisième valve comporte un organe de valve (51 ; 61) qui change continuellement le degré d'ouverture en accord avec une pression égale à ou supérieure à la première pression et égale à ou inférieure à la seconde pression.

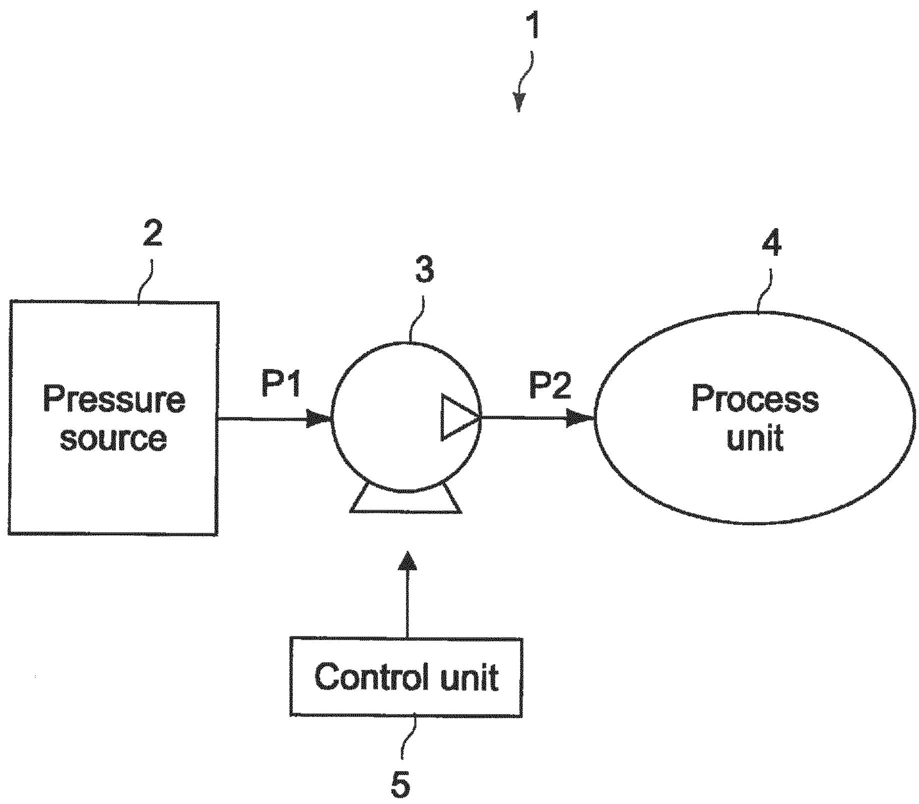



FIG.1

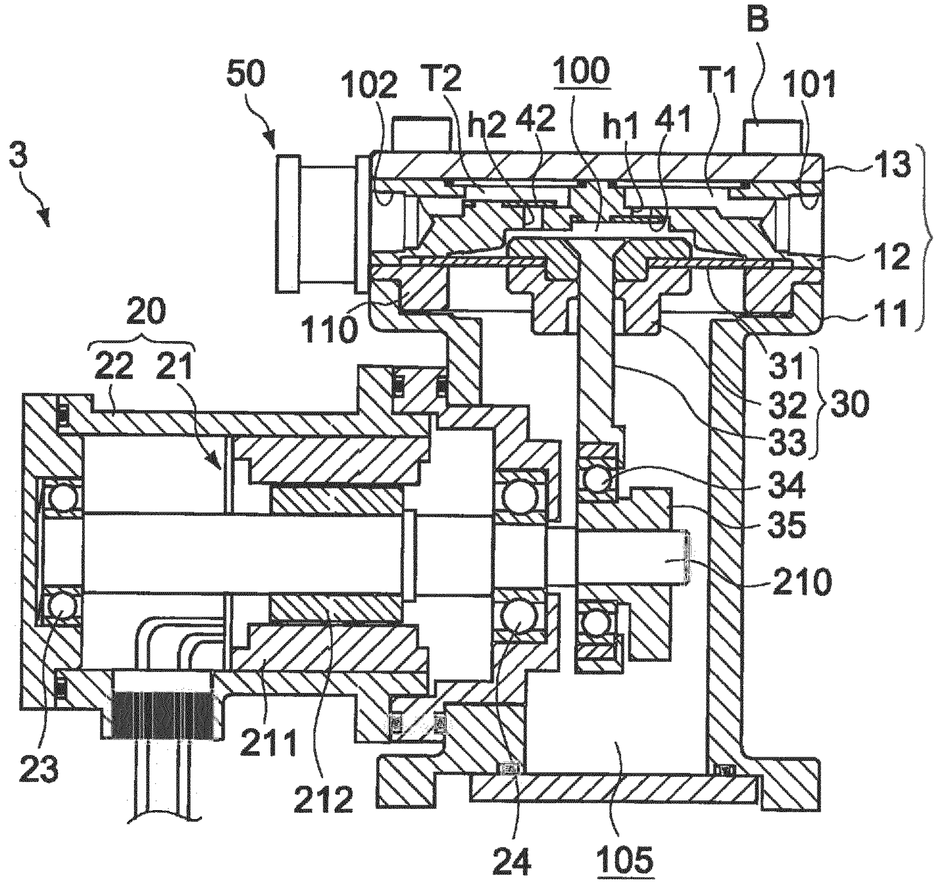
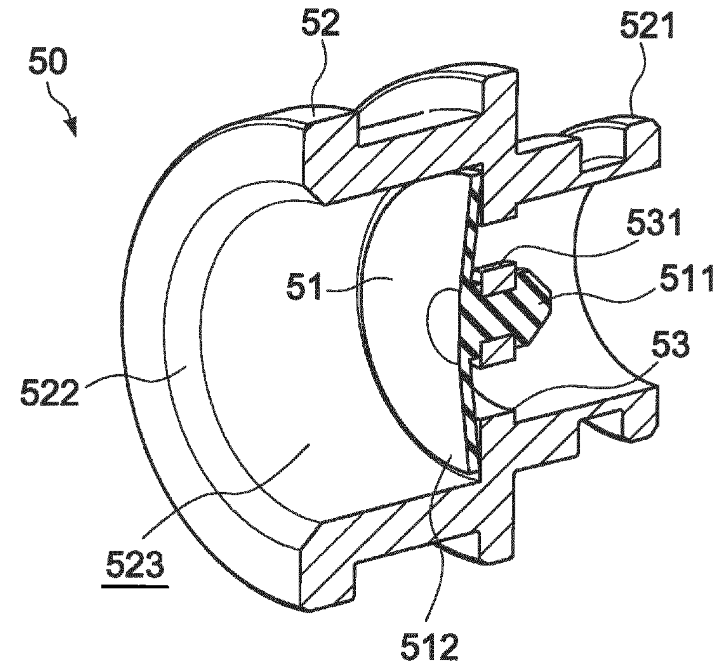
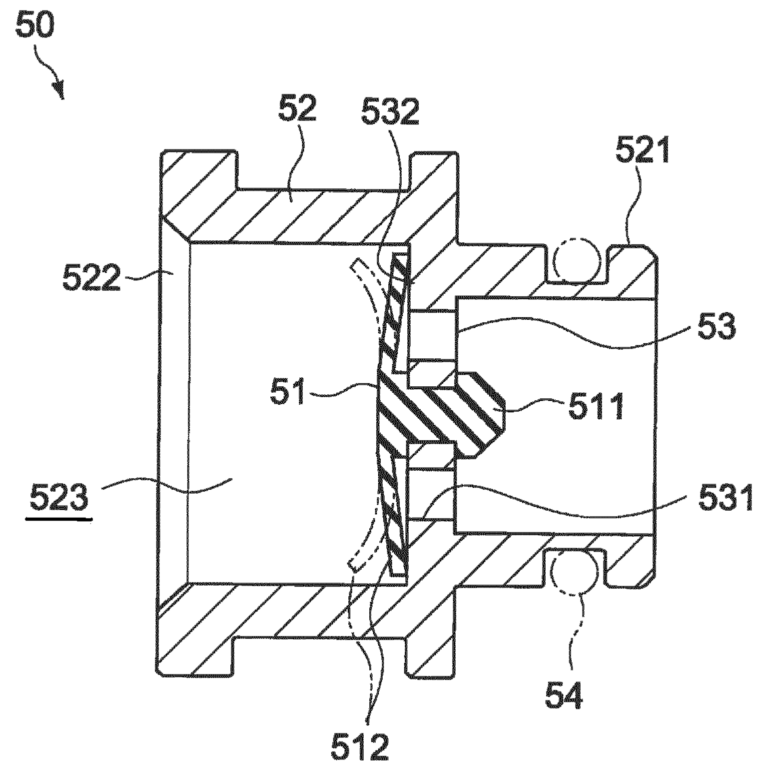

B
50
102
T2
100
T1
101
h2
42
h1
41
3
13
12
10
11
110
20
22
21
31
32
30
33
34
35
210
23
211
212
24
105

FIG.2



50
52
521
531
51
511
53
522
523
512


FIG.3



50
52
532
521
522
53
51
511
523
531
54
512


FIG.4

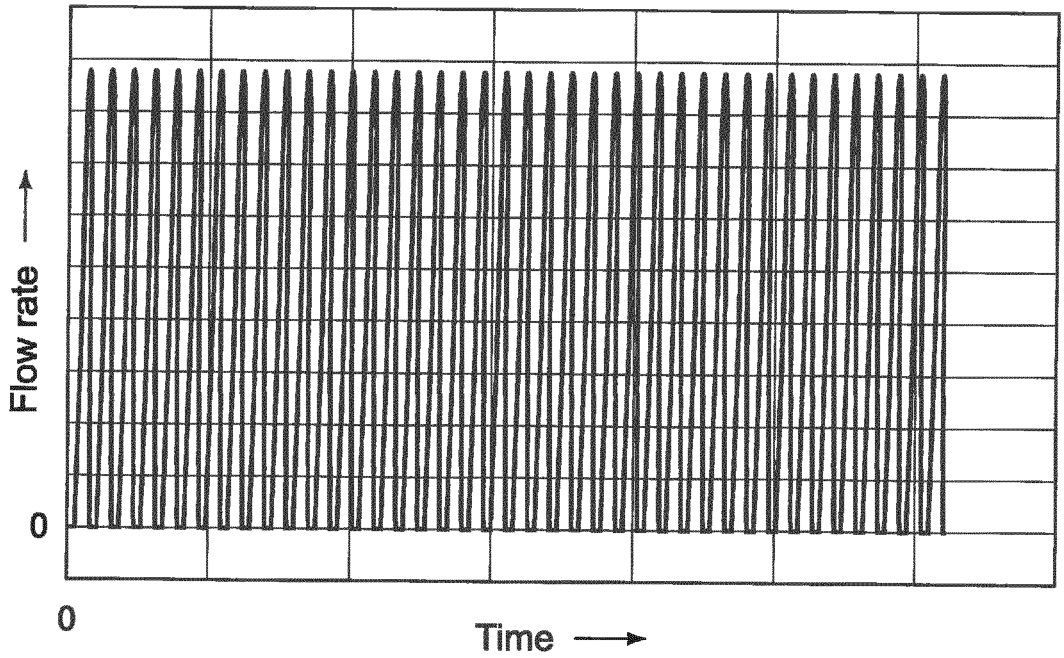



FIG.5

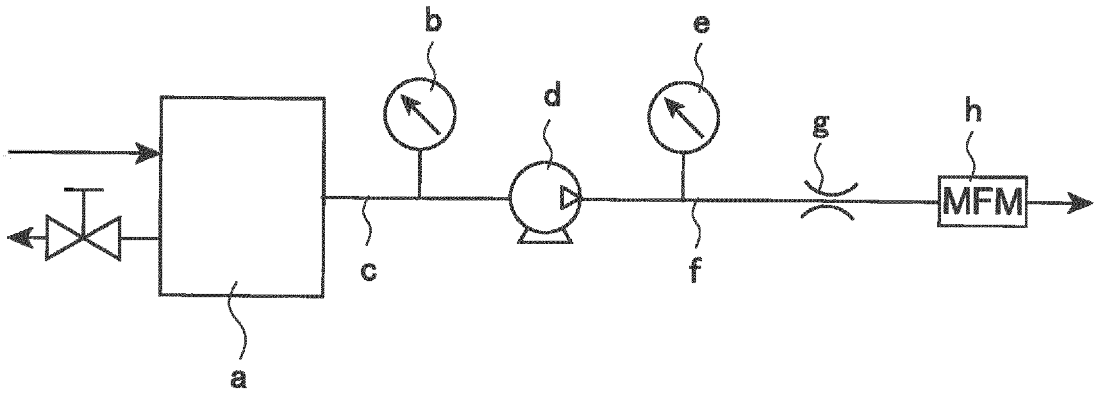



FIG.6

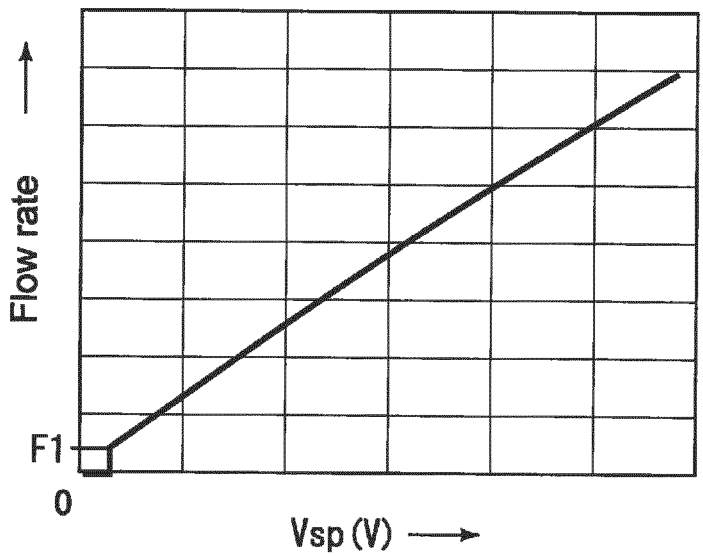



FIG.7

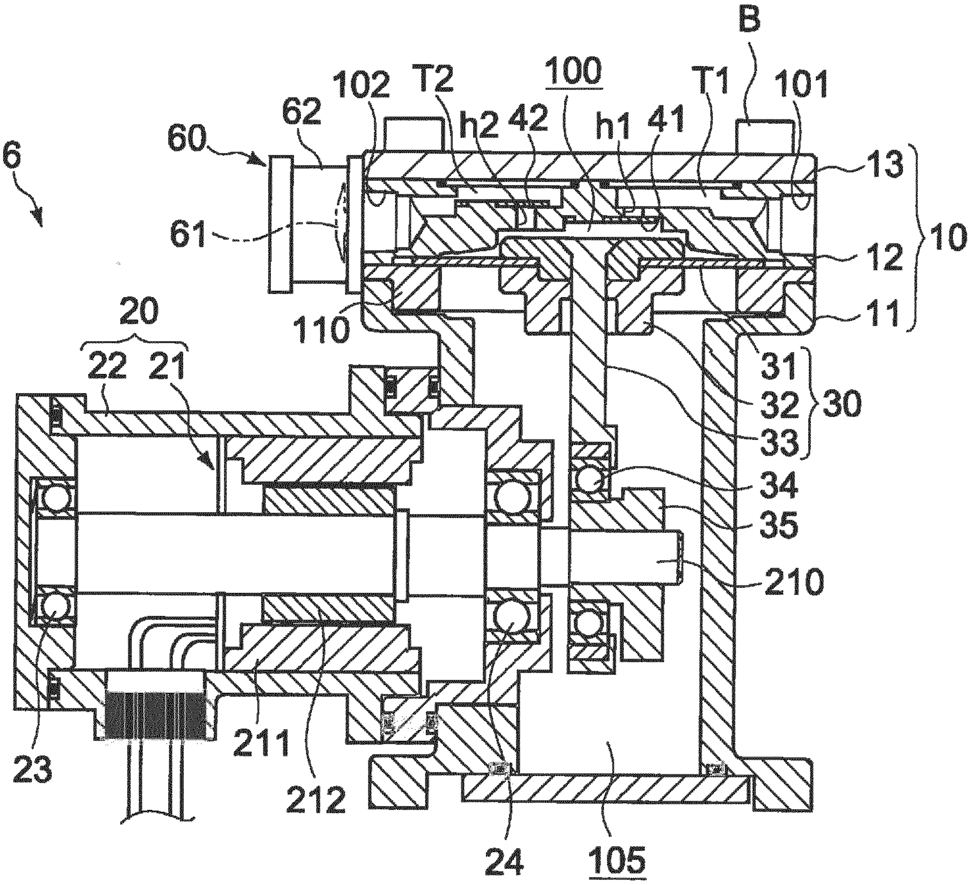

B
102
T2
100
T1
101
62
h2
42
h1
41
60
6
13
61
12
10
110
11
20
22
21
31
32
30
33
34
35
210
23
211
212
24
105

FIG.8

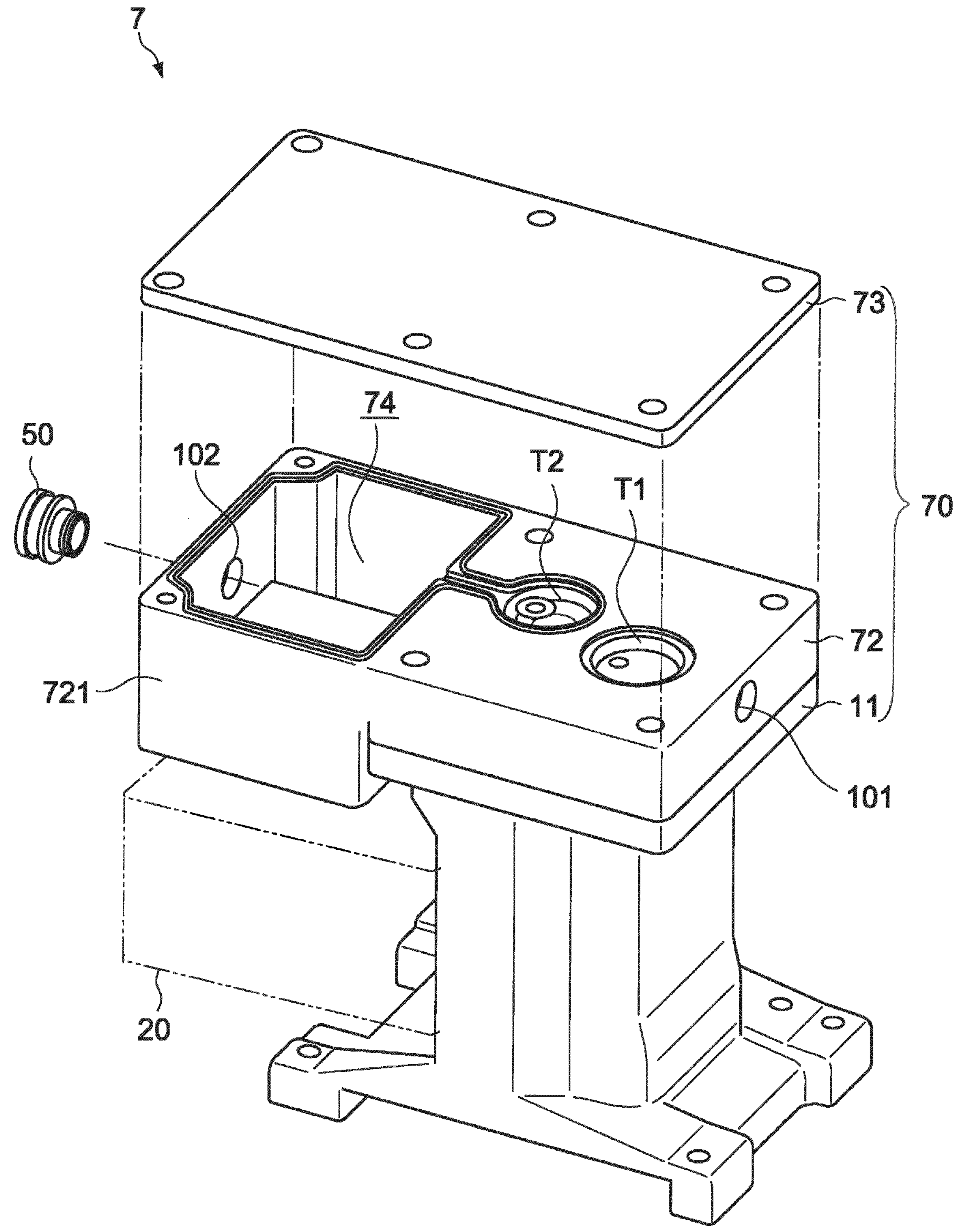
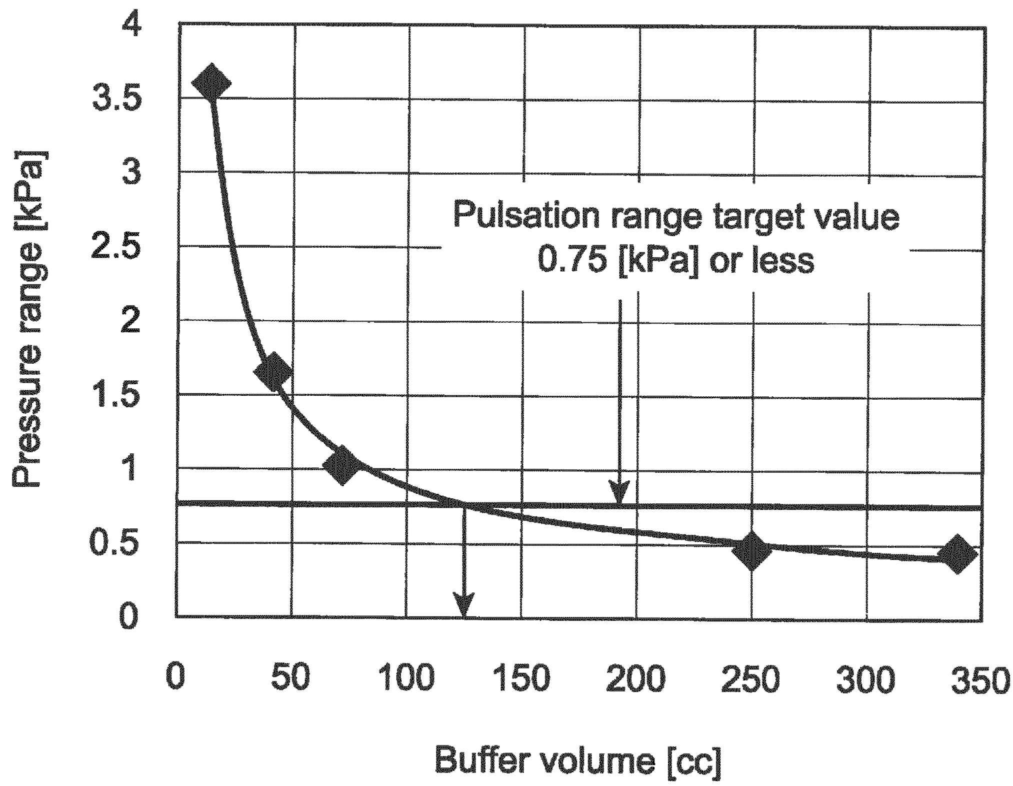



FIG.9



4
3.5
3
2.5
2
1.5
1
0.5
0
Pressure range [kPa]
Pulsation range target value
0.75 [kPa] or less
0
50
100
150
200
250
300
350
Buffer volume [cc]


FIG.10

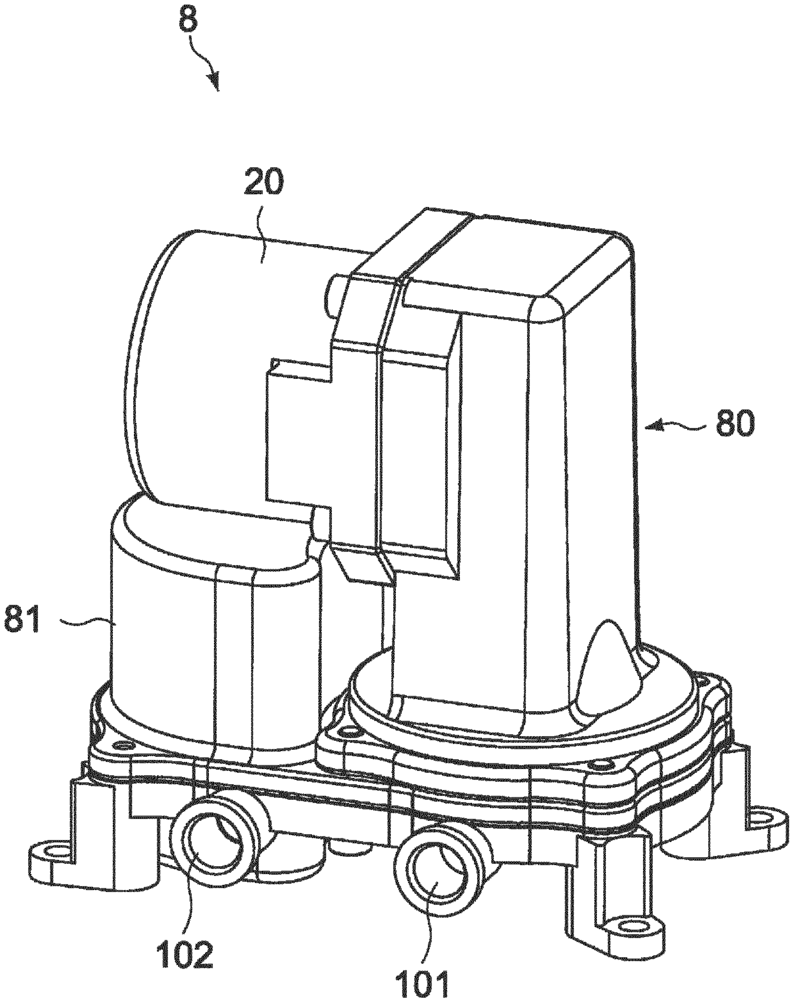



FIG.11

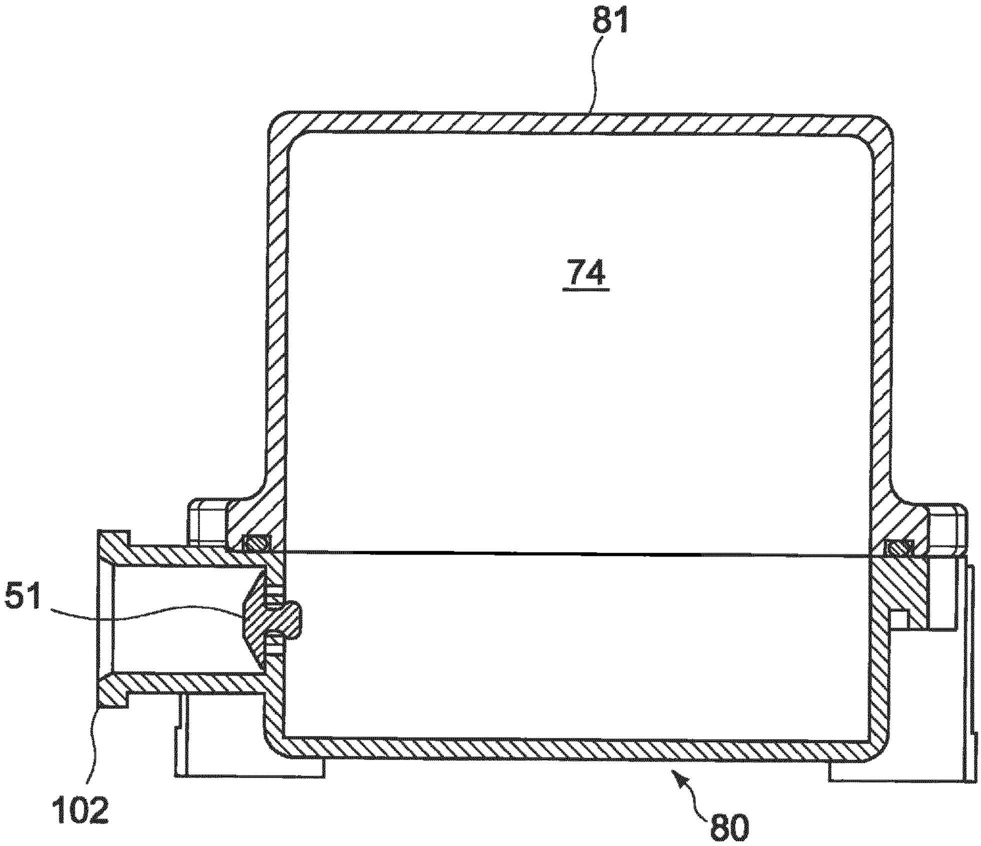



FIG.12

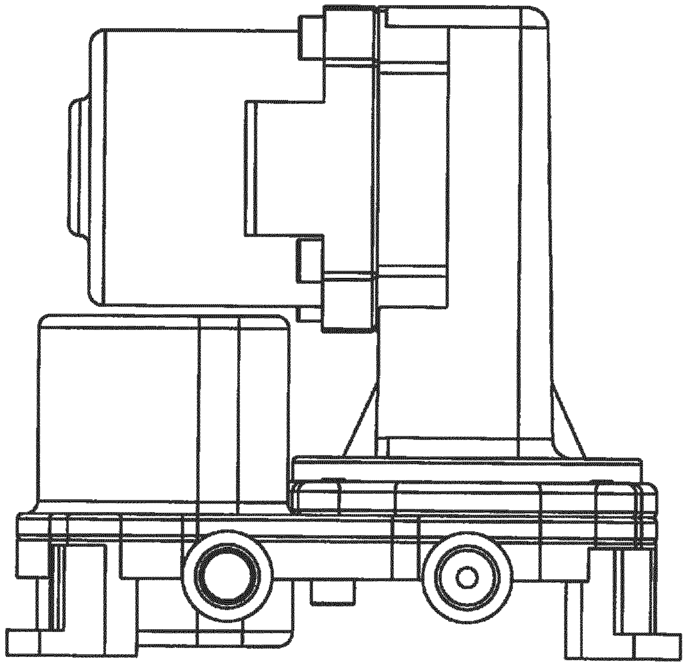


FIG.13

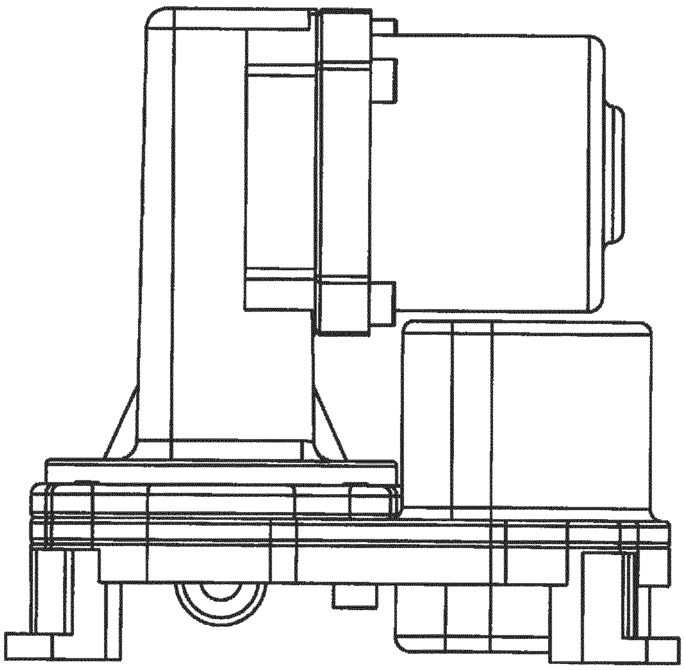


FIG.14

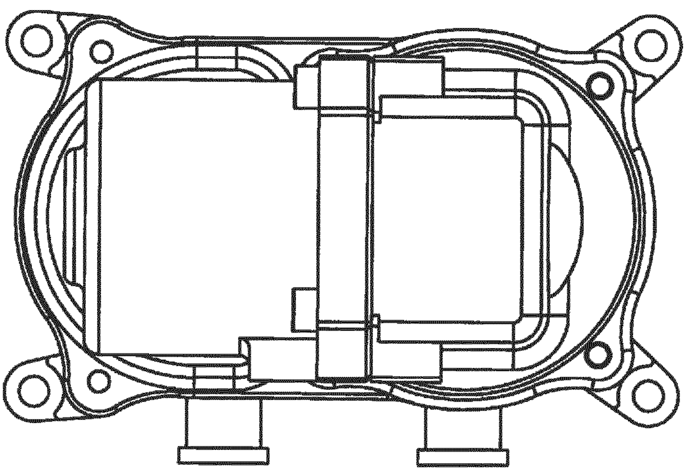


FIG.15

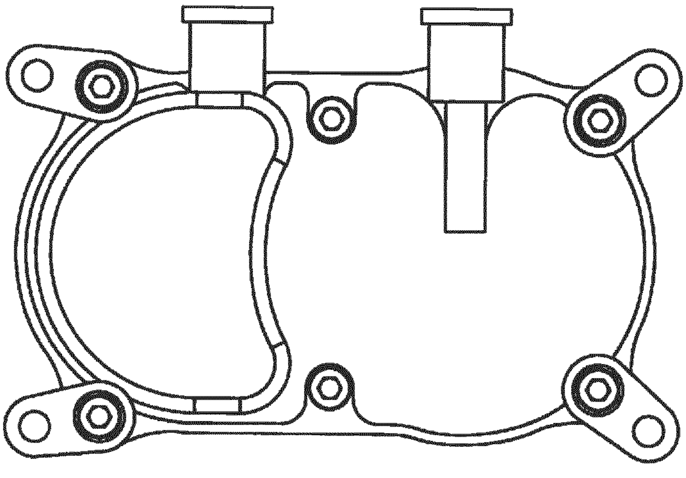


FIG.16

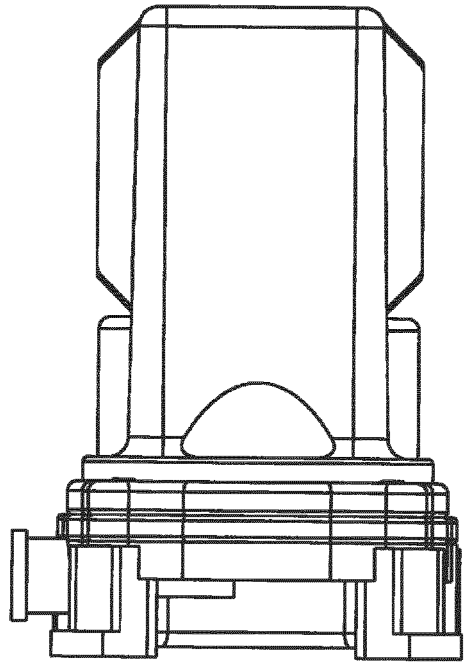


FIG.17

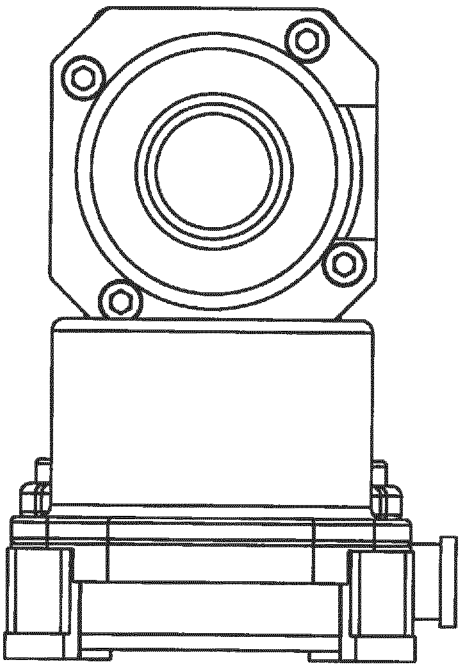


FIG.18

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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